US010414209B2

(12) **United States Patent**
Benzing, II

(10) **Patent No.: US 10,414,209 B2**
(45) **Date of Patent: *Sep. 17, 2019**

(54) **NON-PNEUMATIC TIRE WITH GEODESIC PLY AND BEAD**

(71) Applicant: **The Goodyear Tire & Rubber Company**, Akron, OH (US)

(72) Inventor: **James Alfred Benzing, II**, Canton, OH (US)

(73) Assignee: **The Goodyear Tire & Rubber Company**, Akron, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 96 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **15/376,720**

(22) Filed: **Dec. 13, 2016**

(65) **Prior Publication Data**

US 2017/0174004 A1 Jun. 22, 2017

Related U.S. Application Data

(60) Provisional application No. 62/270,856, filed on Dec. 22, 2015.

(51) **Int. Cl.**

B60C 7/10	(2006.01)
B60C 7/00	(2006.01)
B60C 7/14	(2006.01)

(52) **U.S. Cl.**
CPC ***B60C 7/102*** (2013.01); ***B60C 7/00*** (2013.01); ***B60C 7/14*** (2013.01); *B60C 2007/146* (2013.01)

(58) **Field of Classification Search**
CPC .. B60C 7/102; B60C 7/00; B60C 7/14; B60C 2007/146
USPC 152/5
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,016,991 A *	2/1912	Herold	B60C 7/14	152/268
6,068,721 A *	5/2000	Dyer	B29D 30/36	152/554
6,386,258 B1 *	5/2002	Dyer	B60C 9/07	152/542
6,640,859 B1 *	11/2003	Laurent	B60C 7/10	152/246
2004/0187996 A1 *	9/2004	Grah	B60C 1/00	152/516

(Continued)

FOREIGN PATENT DOCUMENTS

FR	2844479 A1	3/2004
FR	2856635 A1	12/2004

(Continued)

OTHER PUBLICATIONS

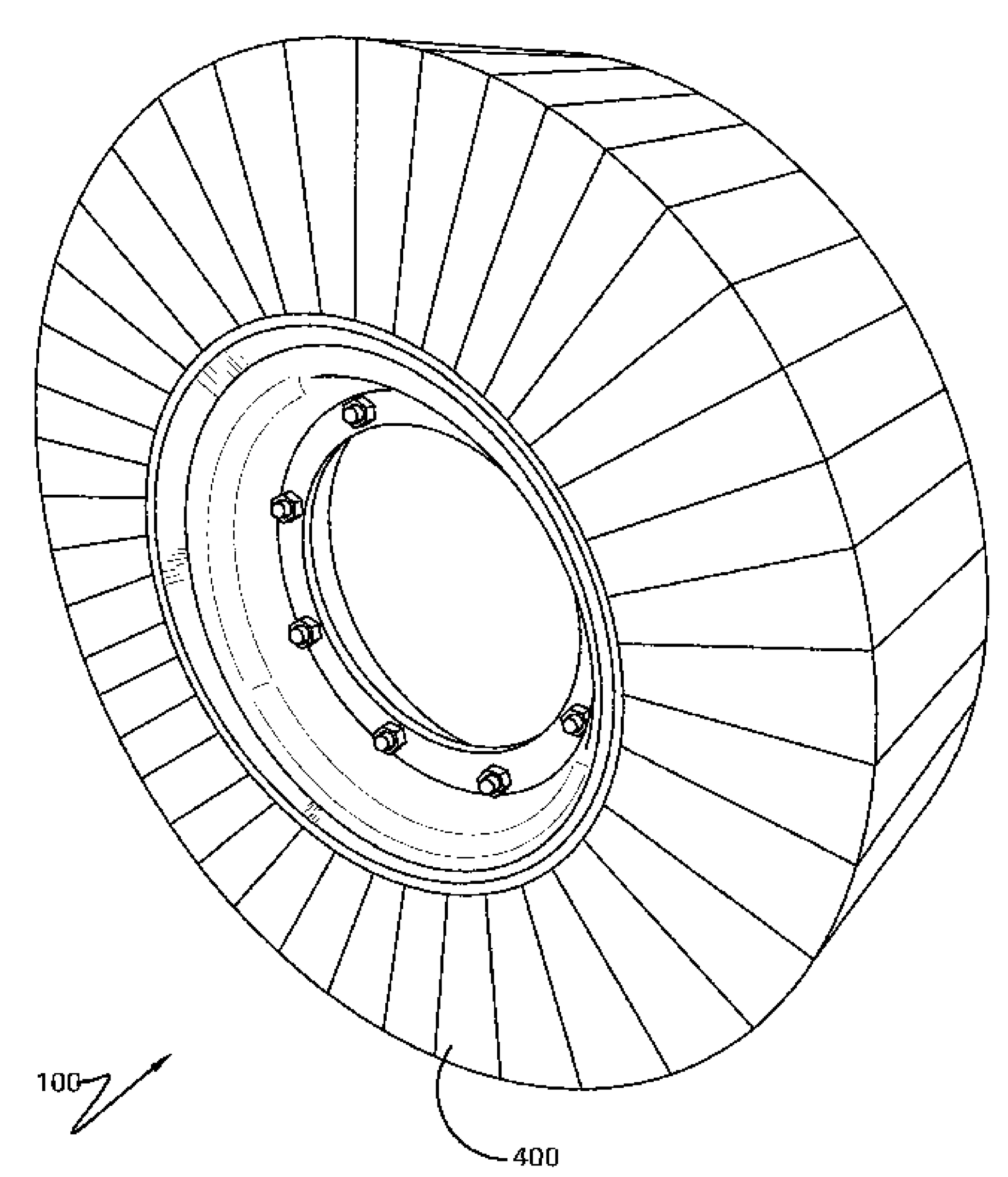
European Search Report dated May 8, 2017 for Application Serial No. EP16203425.

Primary Examiner — S. Joseph Morano
Assistant Examiner — Jean W Charleston
(74) *Attorney, Agent, or Firm* — June E. Rickey

(57) **ABSTRACT**

A non-pneumatic tire is described which includes a ground contacting annular tread portion, a shear band, and a reinforcement structure positioned radially inward of the tread. The reinforcement structure is formed from a plurality of strips, wherein each strip has a first end located radially outward of the shear band and a second end secured to a bead, wherein the plurality of strips do not extend completely across the annular tread portion.

10 Claims, 11 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0022921 A1*	1/2009	Meraldi	....	B29C 70/32 428/36.4

FOREIGN PATENT DOCUMENTS

GB	339403	A	12/1930
WO	02083435	A1	10/2002

* cited by examiner

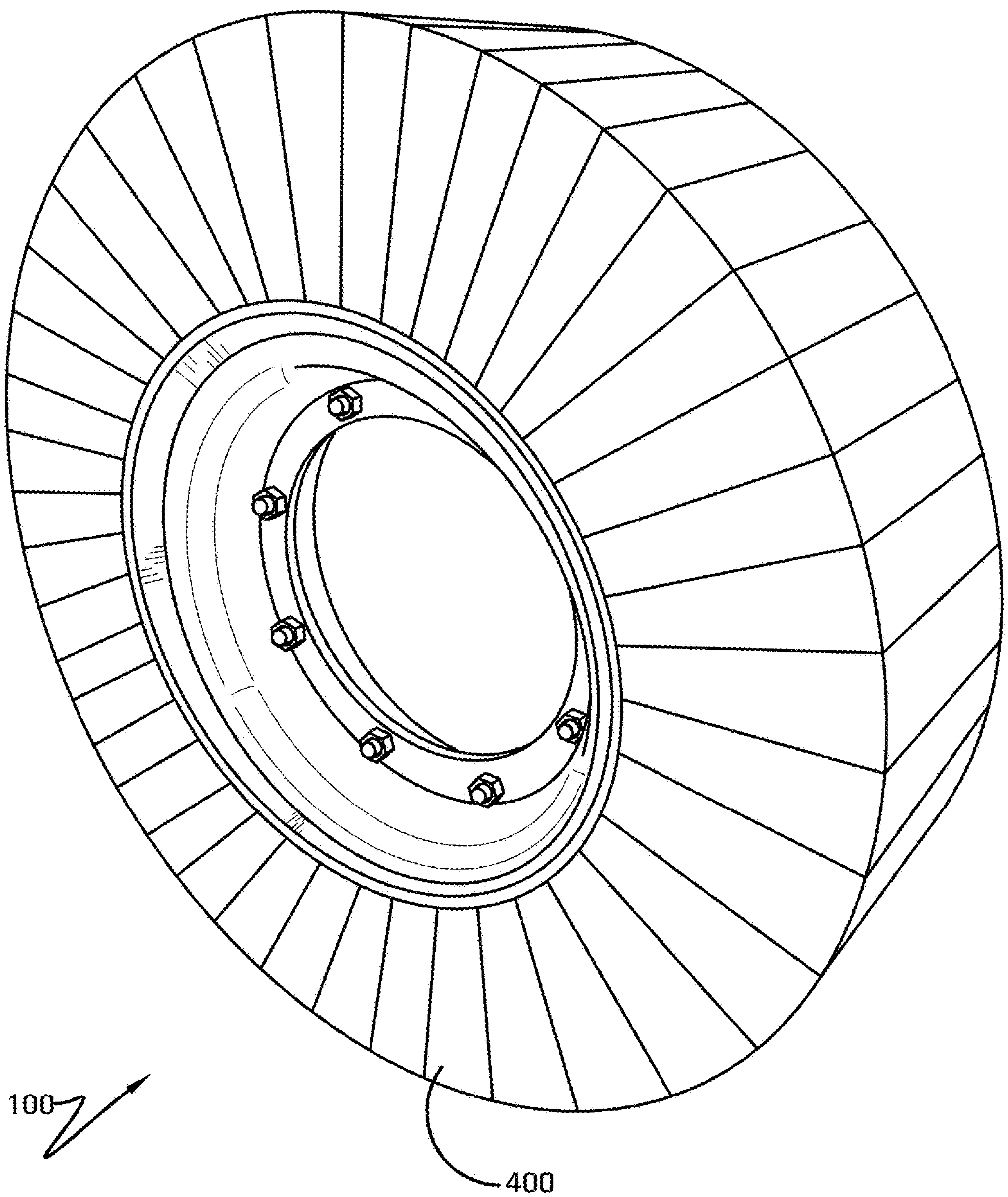


Fig. 1

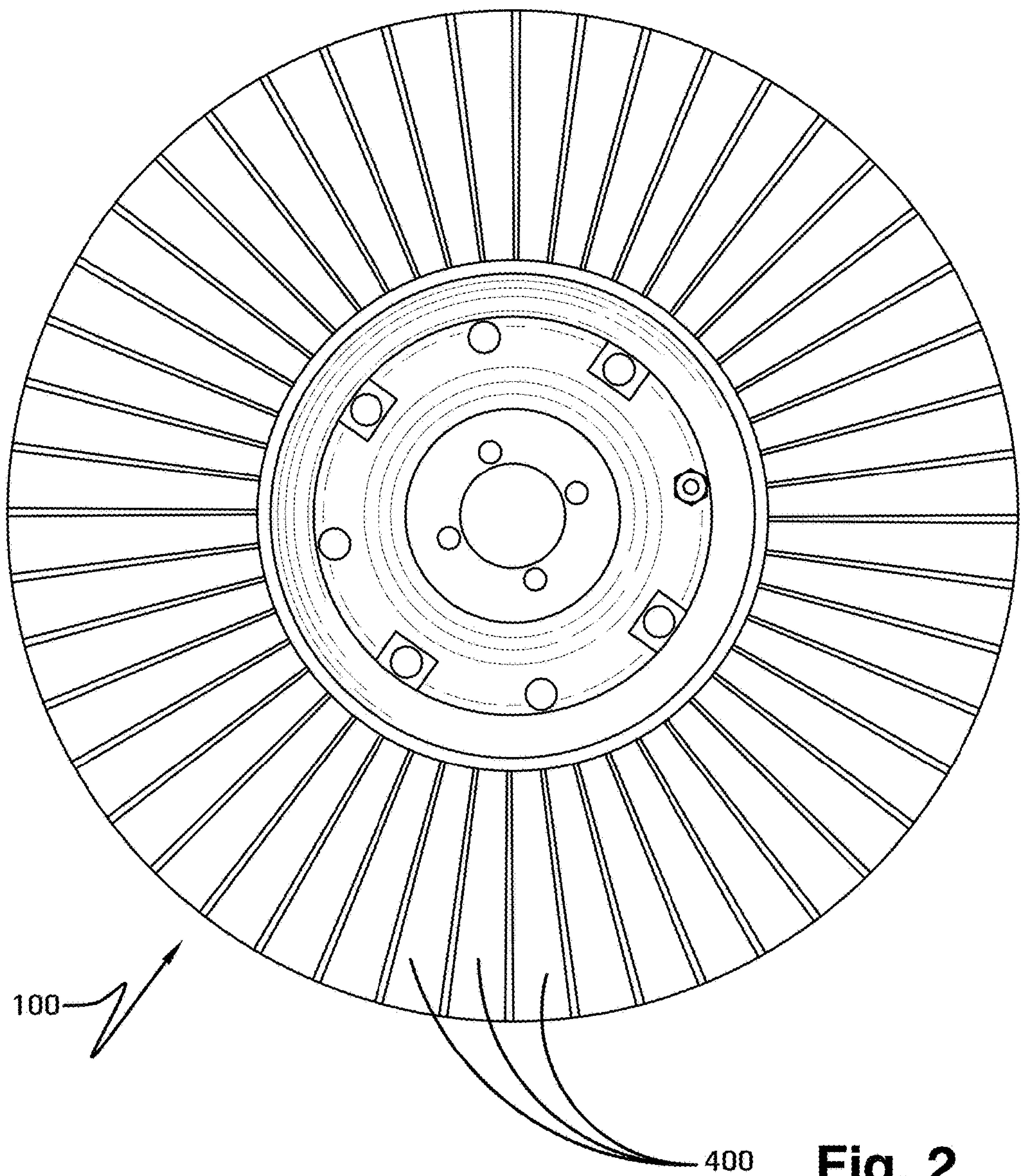


Fig. 2

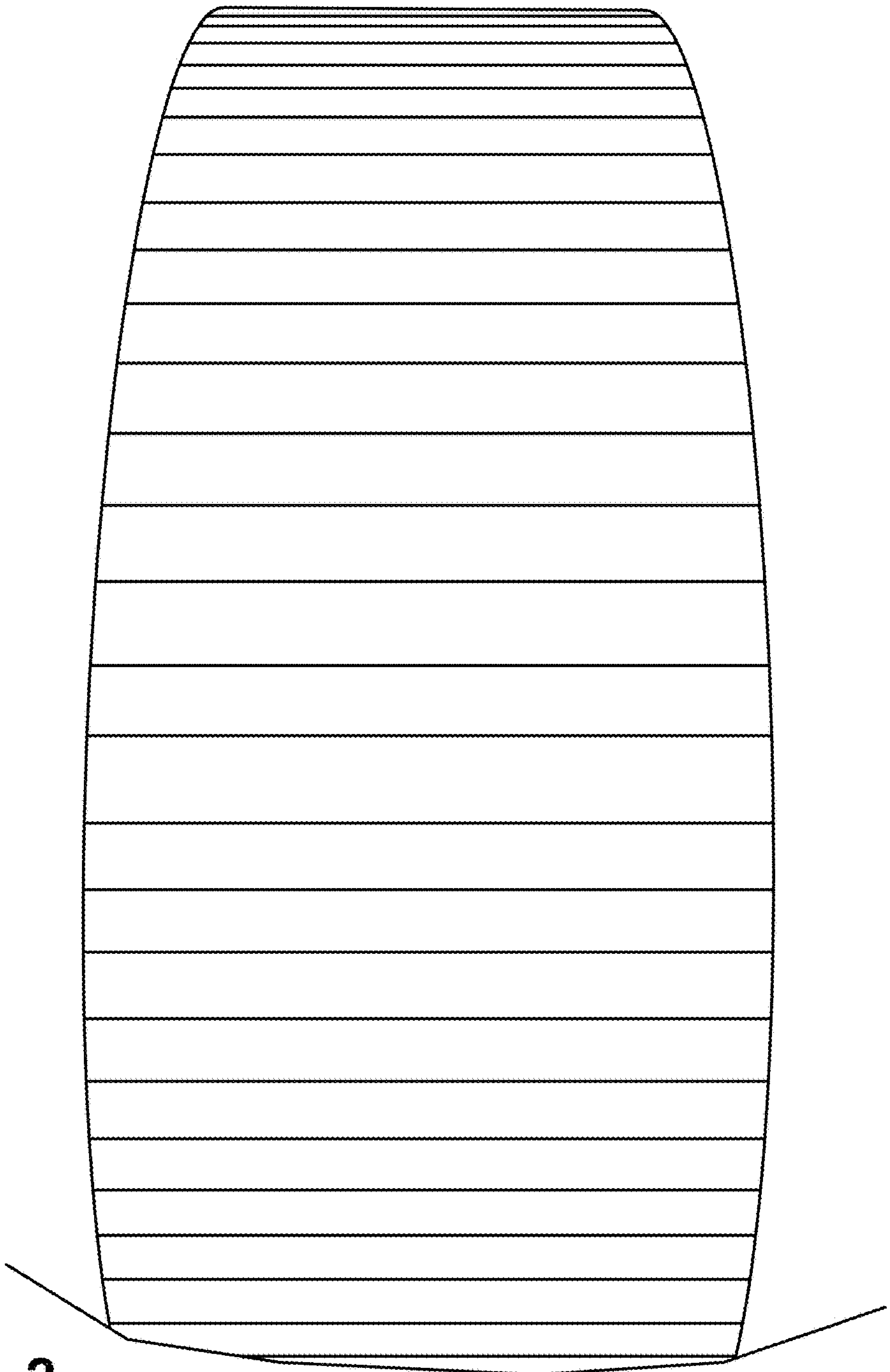


Fig. 3

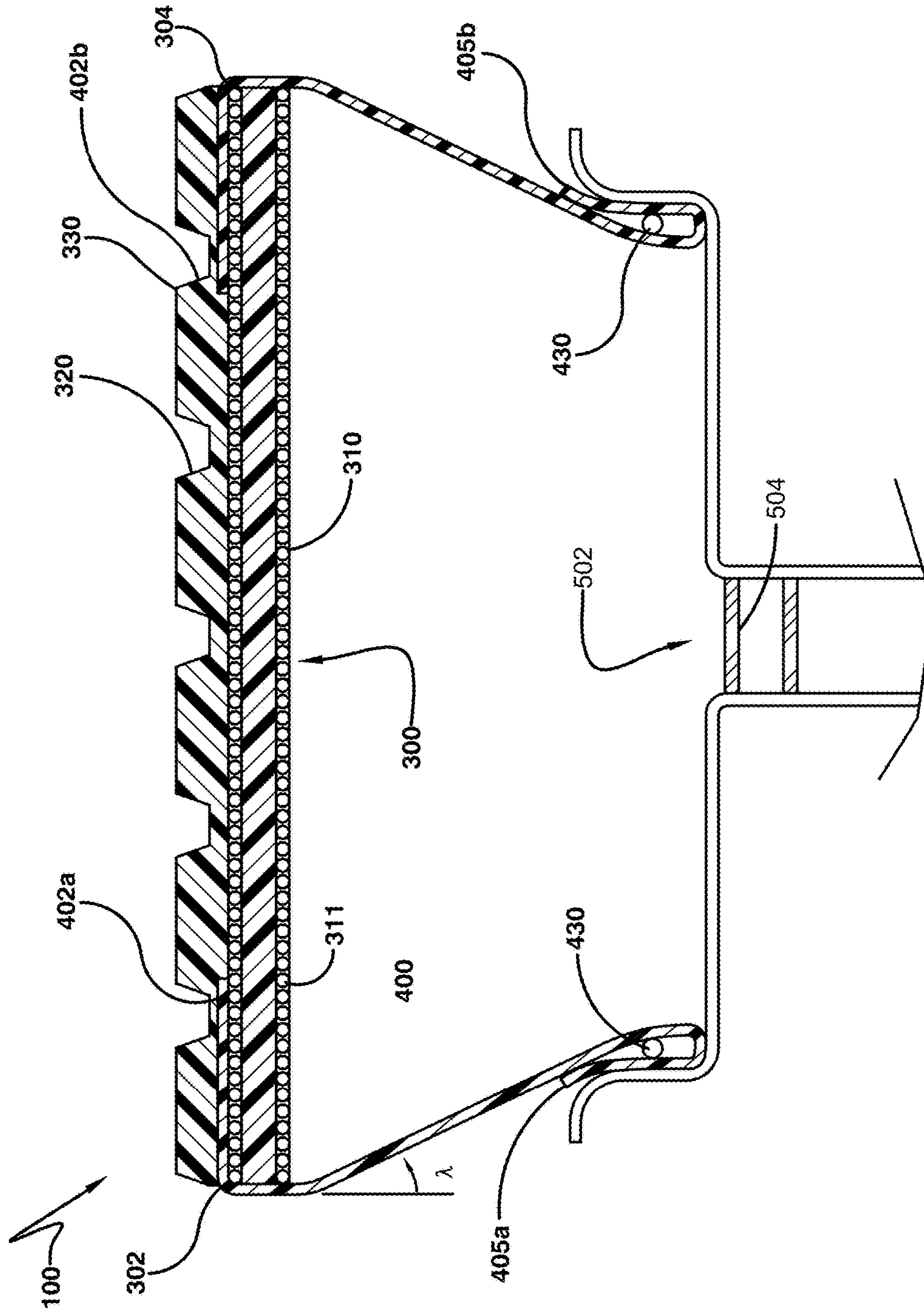

304
402b
405b
330
320
310
430
504
502
300
402a
311
400
430
λ
100
302
405a

Fig. 4

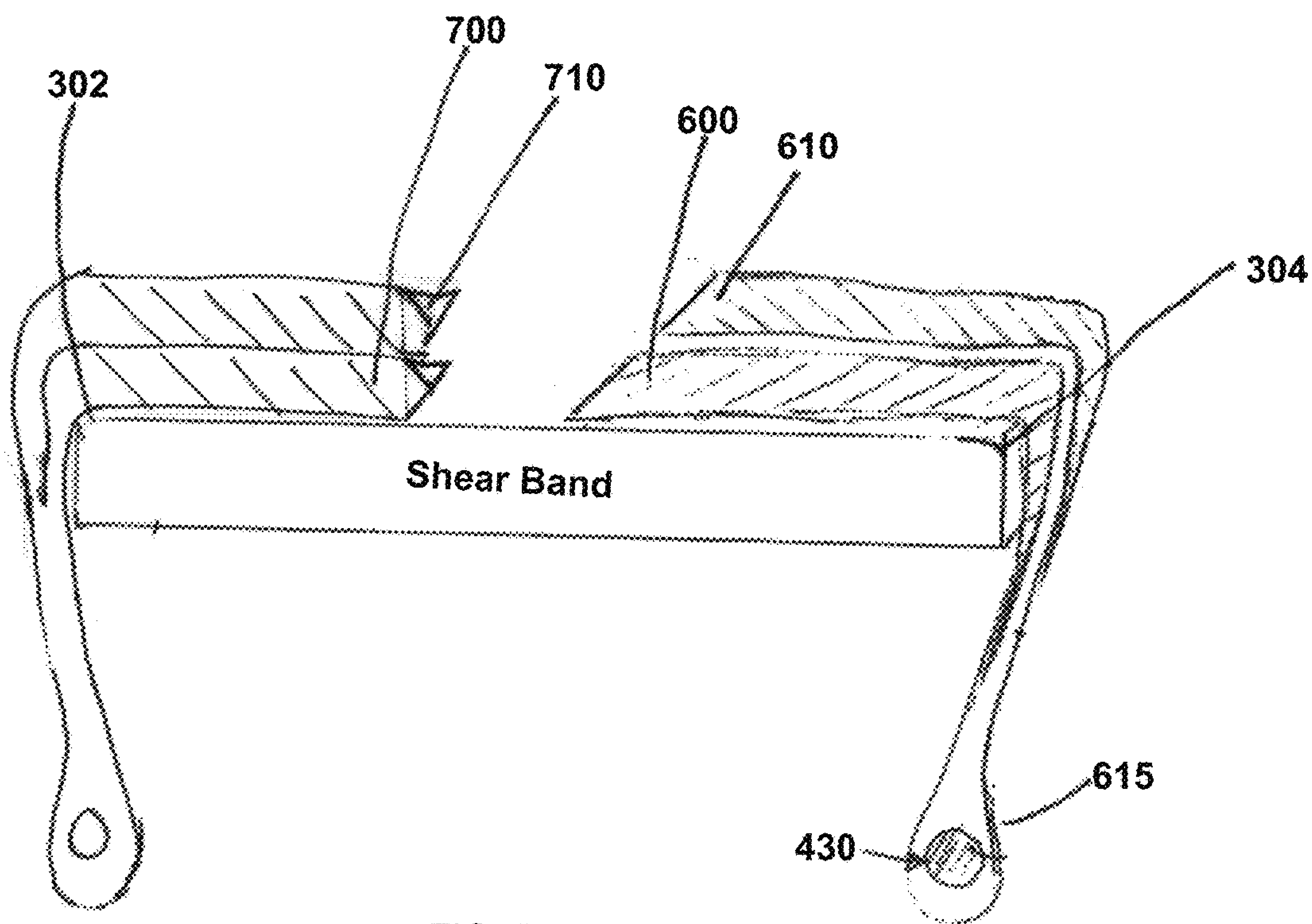


FIG. 5

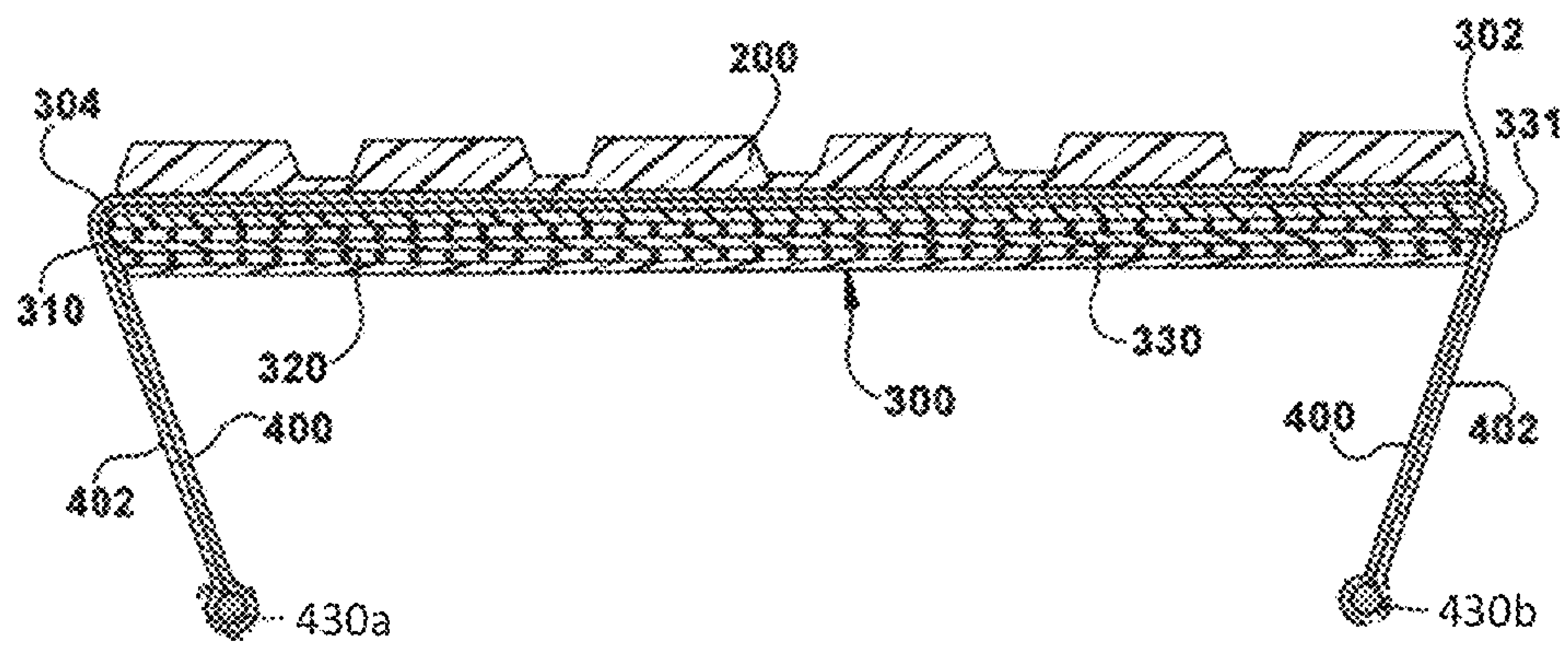


Fig. 6

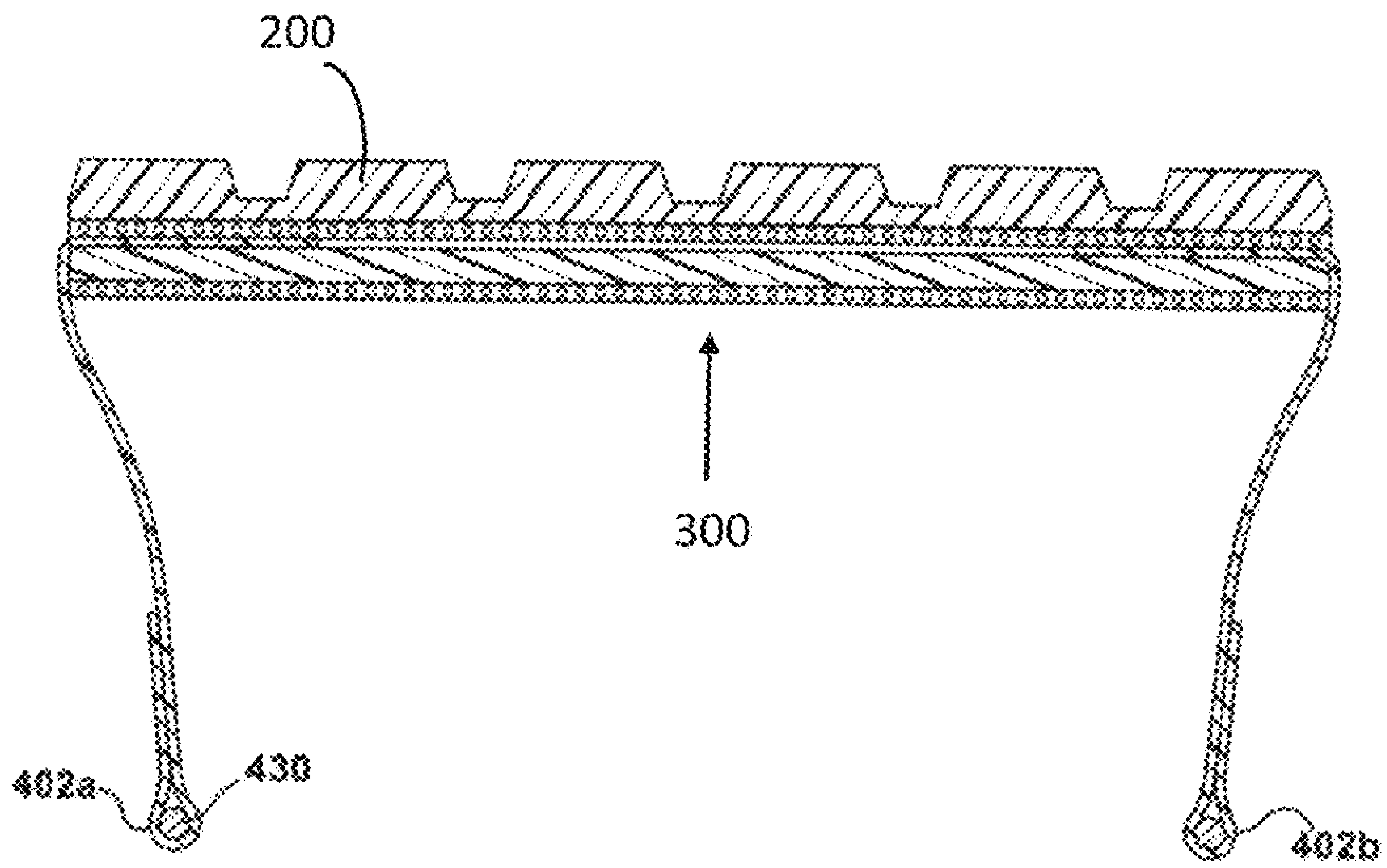


Fig. 7

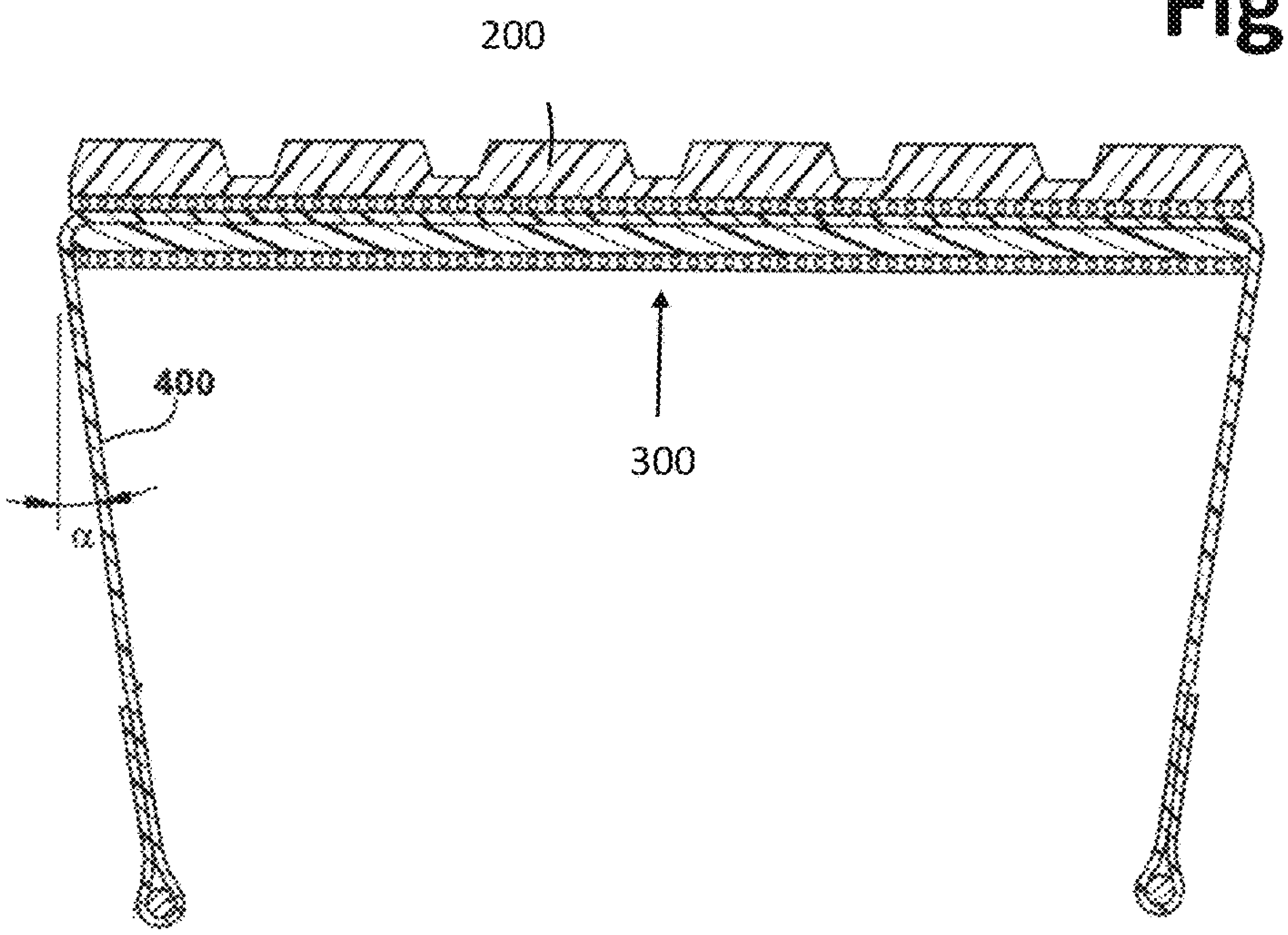


Fig. 8

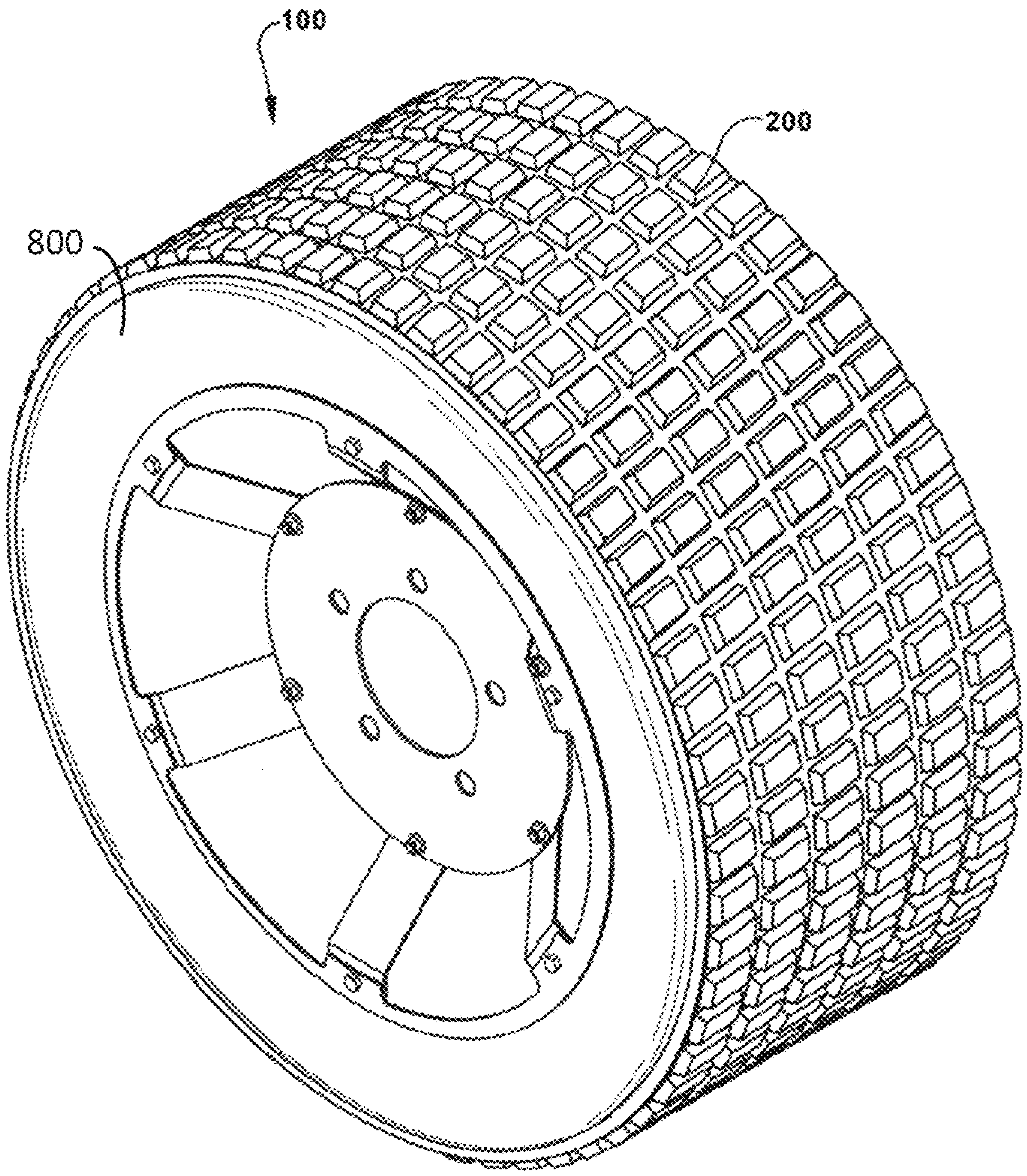


Fig. 9

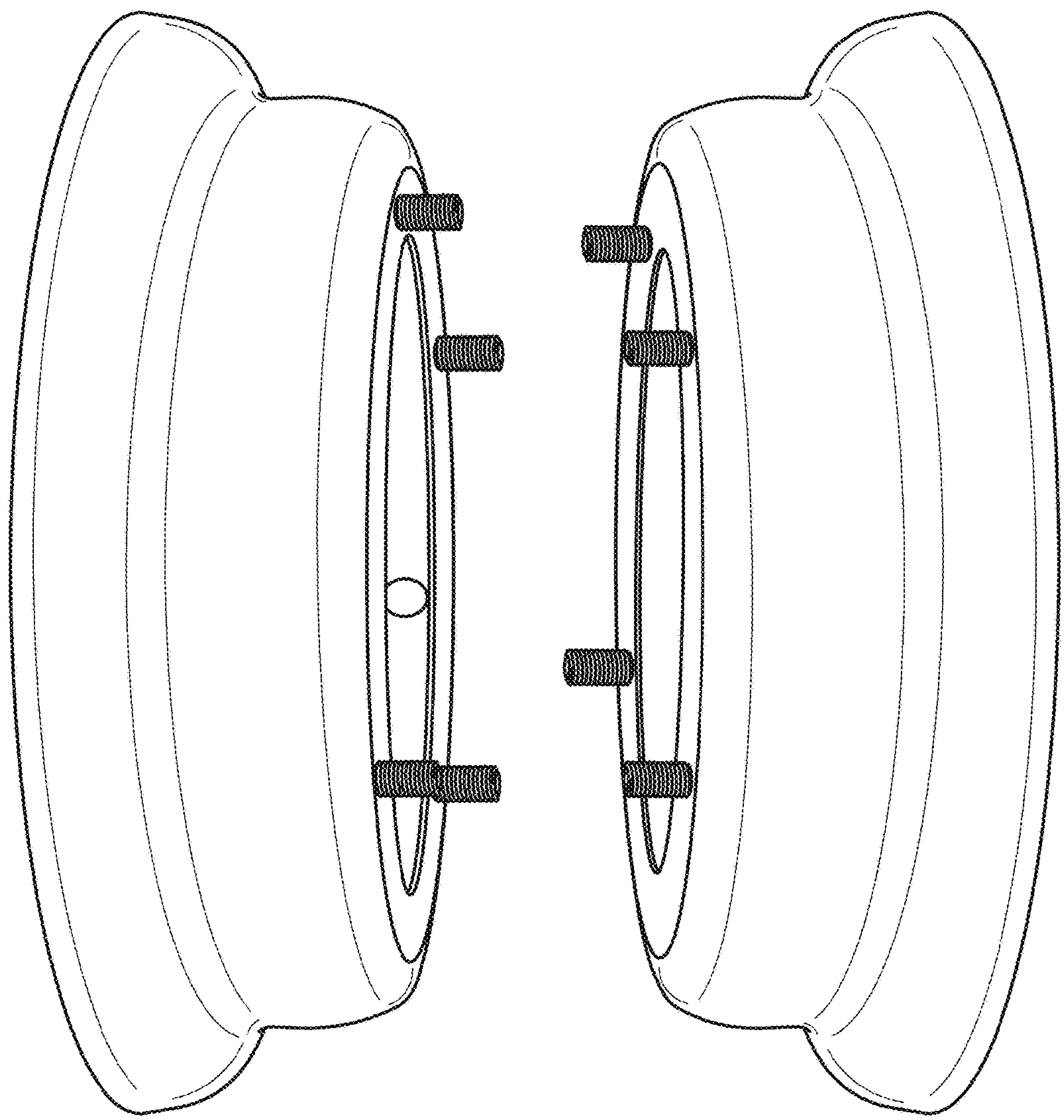


Fig. 10

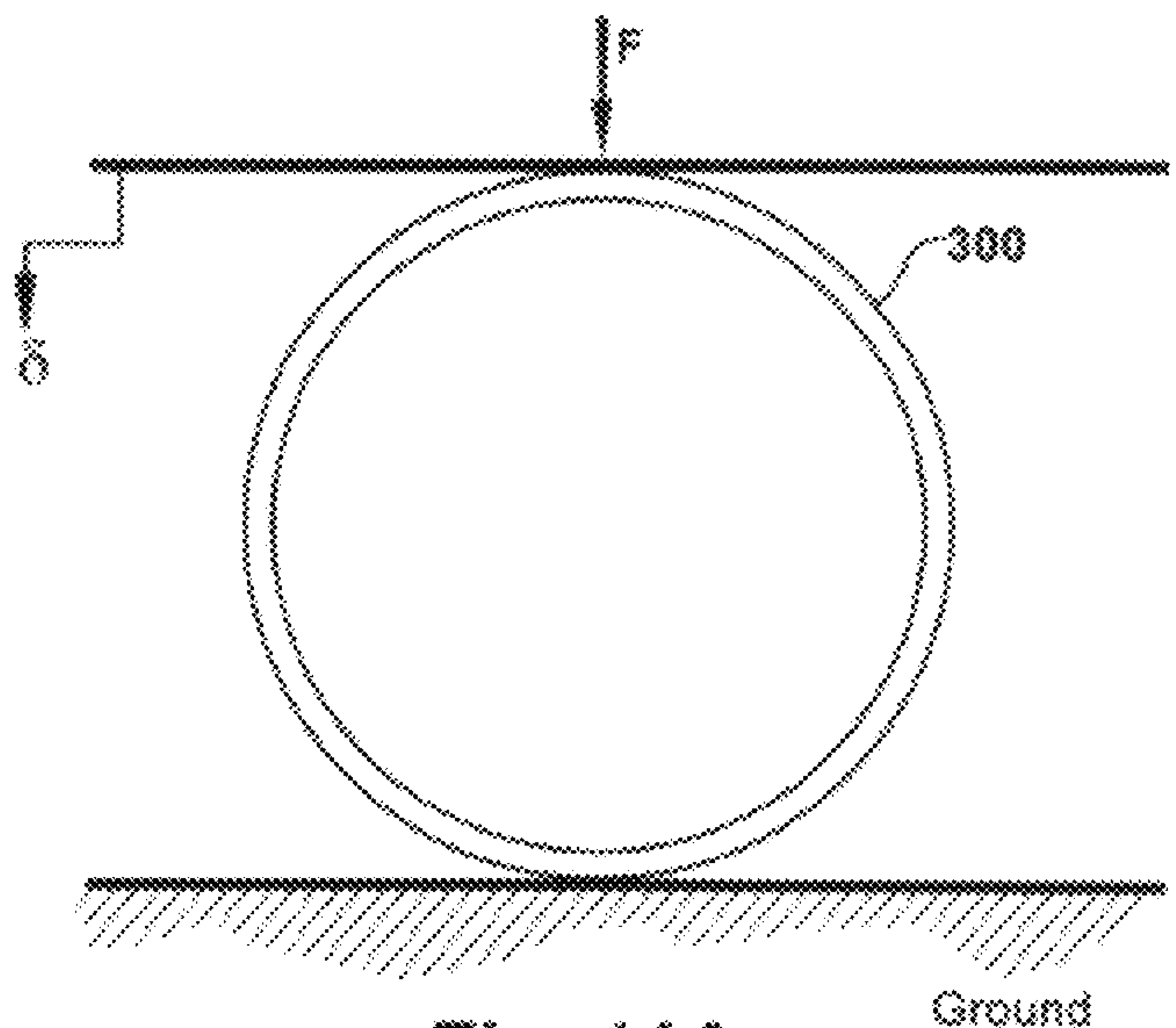


Fig. 11A

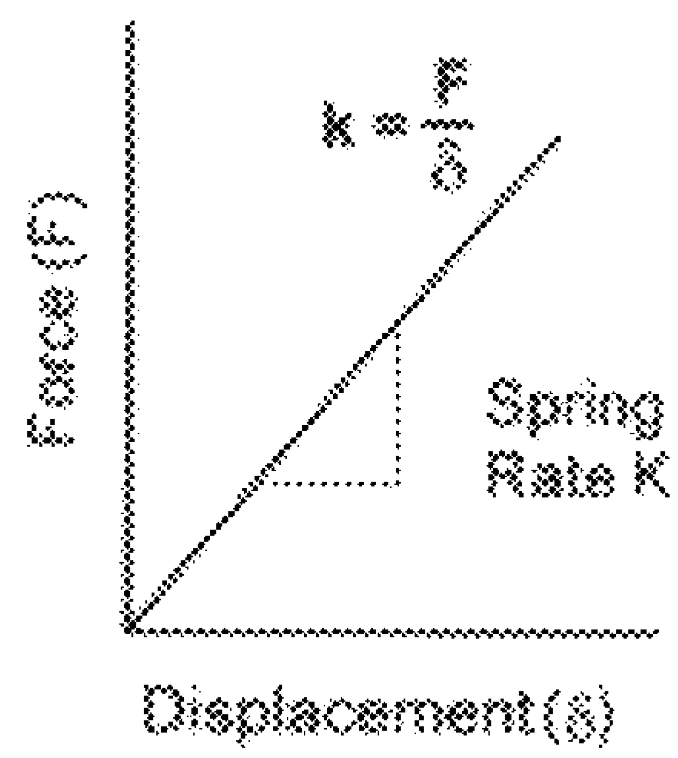


Fig. 11B

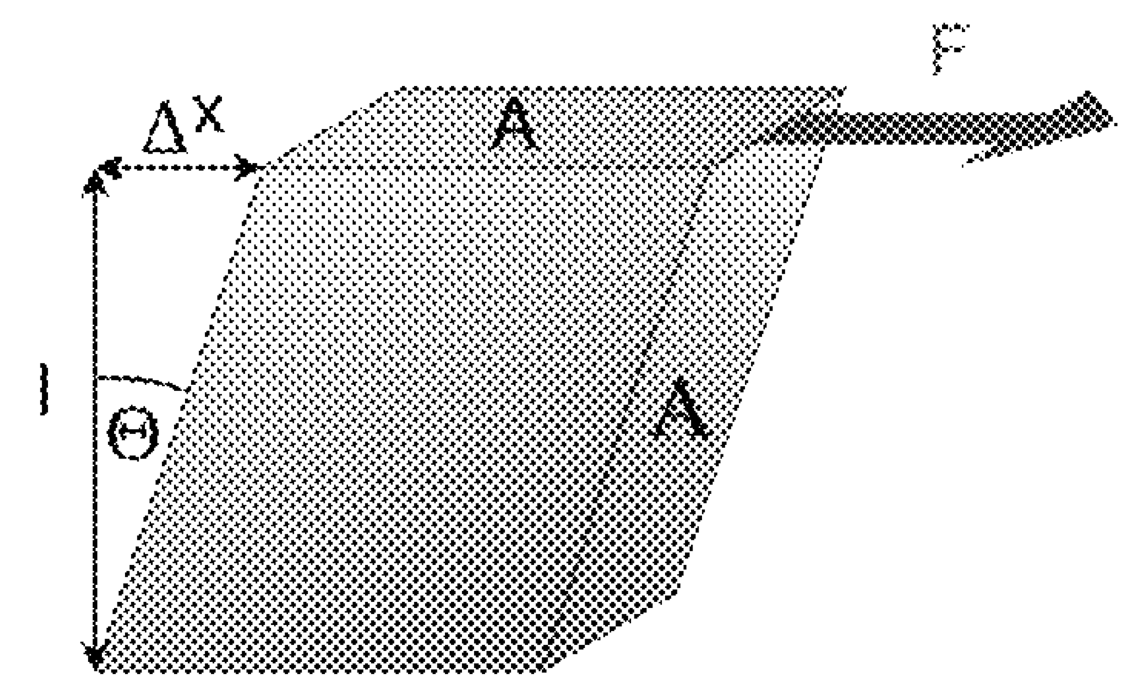


FIG. 12

NON-PNEUMATIC TIRE WITH GEODESIC PLY AND BEAD

FIELD OF THE INVENTION

The present invention relates generally to vehicle tires and non-pneumatic tires, and more particularly, to a non-pneumatic tire.

BACKGROUND OF THE INVENTION

The pneumatic tire has been the solution of choice for vehicular mobility for over a century. The pneumatic tire is a tensile structure. The pneumatic tire has at least four characteristics that make the pneumatic tire so dominate today. Pneumatic tires are efficient at carrying loads, because all of the tire structure is involved in carrying the load. Pneumatic tires are also desirable because they have low contact pressure, resulting in lower wear on roads due to the distribution of the load of the vehicle. Pneumatic tires also have low stiffness, which ensures a comfortable ride in a vehicle. The primary drawback to a pneumatic tire is that it requires compressed fluid. A conventional pneumatic tire is rendered useless after a complete loss of inflation pressure.

A tire designed to operate without inflation pressure may eliminate many of the problems and compromises associated with a pneumatic tire. Neither pressure maintenance nor pressure monitoring is required. Structurally supported tires such as solid tires or other elastomeric structures to date have not provided the levels of performance required from a conventional pneumatic tire. A structurally supported tire solution that delivers pneumatic tire-like performance would be a desirous improvement.

Non-pneumatic tires are typically defined by their load carrying efficiency. "Bottom loaders" are essentially rigid structures that carry a majority of the load in the portion of the structure below the hub. "Top loaders" are designed so that all of the structure is involved in carrying the load. Top loaders thus have a higher load carrying efficiency than bottom loaders, allowing a design that has less mass.

Thus an improved non-pneumatic tire is desired that has all the features of the pneumatic tires without the drawback of the need for air inflation is desired.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood through reference to the following description and the appended drawings, in which:

FIG. **1** is a perspective view of a first embodiment of a non-pneumatic tire of the present invention;

FIG. **2** is a side view of the non-pneumatic tire of FIG. **1**;

FIG. **3** is a top view of the non-pneumatic of FIG. **1**;

FIG. **4** is a cross-sectional view of the non-pneumatic tire of FIG. **1**;

FIG. **5** is a first alternative embodiment of the geodesic ply spokes.

FIG. **6** is a second alternative embodiment of the geodesic ply spokes.

FIG. **7** is a cross-sectional view of a third embodiment of the invention.

FIG. **8** is a cross-sectional view of a fourth embodiment of the invention.

FIG. **9** is a perspective view of a fifth embodiment of the invention.

FIG. **10** is a side view of a two piece rim for use with the invention.

FIG. **11***a* illustrates a spring rate test for a shear band, while FIG. **11***b* illustrates the spring rate k determined from the slope of the force displacement curve.

FIG. **12** is the deflection measurement on a shear band from a force F.

DEFINITIONS

The following terms are defined as follows for this description.

"Equatorial Plane" means a plane perpendicular to the axis of rotation of the tire passing through the centerline of the tire.

"Meridian Plane" means a plane parallel to the axis of rotation of the tire and extending radially outward from said axis.

"Hysteresis" means the dynamic loss tangent measured at 10 percent dynamic shear strain and at 25° C.

DETAILED DESCRIPTION OF THE INVENTION

A non-pneumatic tire **100** of the present invention is shown in the enclosed figures. The non-pneumatic tire of the present invention includes a radially outer ground engaging tread **200**, a shear band **300**, and one or more reinforcement layer **400**. The non-pneumatic tire of the present invention is designed to be a top loaded structure, so that the shear band **300** and the reinforcement layer **400** efficiently carries the load. The shear band **300** and the reinforcement layer **400** are designed so that the stiffness of the shear band is directly related to the spring rate of the tire. The reinforcement layer is designed to be a stiff structure that buckles or deforms in the tire footprint and does not compress or carry a compressive load. This allows the rest of structure not in the footprint area the ability to carry the load, resulting in a very load efficient structure. It is desired to minimize this load for the reason above and to allow the shearband to bend to overcome road obstacles. The approximate load distribution is such that approximately 95-100% of the load is carried by the shear band and the upper radial portion of the reinforcement layer **400**, so that the lower portion of the reinforcement structure undergoing compression carries virtually zero of the load, and preferably less than 10%.

The tread portion **200** may be a conventional tread as desired, and may include grooves or a plurality of longitudinally oriented tread grooves forming essentially longitudinal tread ribs there between. Ribs may be further divided transversely or longitudinally to form a tread pattern adapted to the usage requirements of the particular vehicle application. Tread grooves may have any depth consistent with the intended use of the tire. The tire tread **200** may include elements such as ribs, blocks, lugs, grooves, and sipes as desired to improve the performance of the tire in various conditions.

Shear Band

The shear band **300** is preferably annular. A cross-sectional view of the shear band is shown in FIG. **4**. The shear band **300** is located radially inward of the tire tread **200**. The shear band **300** includes a first and second reinforced elastomer layer **310**,**320**. In a first embodiment of a shear band **300**, the shear band is comprised of two inextensible reinforcement layers **310**,**320** arranged in parallel, and separated by a shear matrix **330** of elastomer. Each inextensible layer **310**,**320** may be formed of parallel inextensible reinforcement cords **311**,**321** embedded in an elastomeric coating. The reinforcement cords **311**,**321** may be steel, aramid, nylon, polyester or other inextensible structure. The shear band **300** may further optionally include a third reinforced elastomer layer **340** (not shown) located between the first and second reinforced elastomer layers **310**,**320**.

It is additionally preferred that the outer lateral ends **302**,**304** of the shear band be radiused in order to control the buckled shape of the sidewall and to reduce flexural stresses.

In the first reinforced elastomer layer **310**, the reinforcement cords are oriented at an angle Φ in the range of 0 to about +/−10 degrees relative to the tire equatorial plane. In the second reinforced elastomer layer **320**, the reinforcement cords are oriented at an angle φ in the range of 0 to about +/−10 degrees relative to the tire equatorial plane. Preferably, the angle Φ of the first layer is in the opposite direction of the angle φ of the reinforcement cords in the second layer. That is, an angle +Φ in the first reinforced elastomeric layer and an angle −φ in the second reinforced elastomeric layer.

The shear matrix **330** has a radial thickness in the range of about 0.10 inches to about 0.2 inches, more preferably about 0.15 inches. The shear matrix is preferably formed of an elastomer material having a shear modulus G_m in the range of 15 to 80 MPa, and more preferably in the range of 40 to 60 MPA.

The shear band has a shear stiffness GA. The shear stiffness GA may be determined by measuring the deflection on a representative test specimen taken from the shear band. The upper surface of the test specimen is subjected to a lateral force F as shown below. The test specimen is a representative sample taken from the shear matrix material, having the same radial thickness.

The shear stiffness GA is then calculated from the following equation:

$$GA=F*L/\Delta X$$

The shear band has a bending stiffness EI. The bending stiffness EI may be determined from beam mechanics using the three point bending test subjected to a test specimen representative of the shear band. It represents the case of a beam resting on two roller supports and subjected to a concentrated load applied in the middle of the beam. The bending stiffness EI is determined from the following equation: $EI=PL^3/48*\Delta X$, where P is the load, L is the beam length, and ΔX is the deflection.

It is desirable to maximize the bending stiffness of the shearband EI and minimize the shear band stiffness GA. The acceptable ratio of GA/EI would be between 0.01 and 20, with a preferred range between 0.01 and 5. EA is the extensible stiffness of the shear band, and it is determined experimentally by applying a tensile force and measuring the change in length. The ratio of the EA to EI of the shearband is acceptable in the range of 0.02 to 100 with a preferred range of 1 to 50. The shear band **300** preferably can withstand a maximum shear strain in the range of 15-30%.

The shear band **300** has a spring rate k that may be determined experimentally by exerting a downward force on a horizontal plate at the top of the shear band and measuring the amount of deflection as shown in FIG. **11***a*. The spring rate k is determined from the slope of the Force versus deflection curve, as shown in FIG. **11***b*.

The non-pneumatic tire has an overall spring rate k_t that is determined experimentally. The non-pneumatic tire is mounted upon a rim, and a load is applied to the center of the tire through the rim. The spring rate k_t is determined from the slope of the Force versus deflection curve. The spring rate k_t is preferably in the range of 500 to 1000 for small low speed vehicles such as lawn mowers.

The invention is not limited to the shear band structure disclosed herein, and may comprise any structure which has a GA/EI in the range of 0.01 to 20, or a EA/EI ratio in the range of 0.02 to 100, or a spring rate k_t in the range of 500 to 1000, as well as any combinations thereof. More preferably, the shear band has a GA/EI ratio of 0.01 to 5, or an EA/EI ratio of 1 to 50 and any subcombinations thereof. The tire tread is preferably wrapped about the shear band and is preferably integrally molded to the shear band.

Reinforcement Structure

A first embodiment of the non-pneumatic tire of the present invention is shown in FIG. **1**-**4**. The reinforcement structure **400** functions to carry the load transmitted from the shear layer. The reinforcement structure **400** is primarily loaded in tension and shear, and carries no load in compression. As shown in FIGS. **1**-**2**, the reinforcement structure is formed of a plurality of strips oriented in the radial direction. The strips may overlap. The reinforcement strips **400** may comprise any fabric or flexible structure such as nylon, polyester, cotton, rubber. Preferably, the reinforcement strips **400** comprise a reinforced rubber or ply strip formed of parallel reinforcements that are nylon, polyester or aramid. The reinforcement strips are preferably about 0.25 to 0.5 inches wide.

As shown in FIG. **4**, each reinforcement strip **400** has a first end **402** *a,b* that is located radially outward of the shear band **300** and axially inward of the lateral edges **302**,**304** of the shear band. The first ends **402***a,b* may extend completely across the crown or not. The reinforcement strip **400** extends radially inward and wraps about a bead **430**, terminating in a terminal end **405***a,b*. The bead **430** is an annular inextensible member, and made of conventional wire fabrics. The bead **430** is smaller than a bead used in a pneumatic tire for the same size. Thus the non-pneumatic tire is secured to a conventional tire rim known to those skilled in the art by a bead.

Preferably, the reinforced strips are oriented in the radial direction. It is preferred that tire ply be used as the reinforcement material for several reasons. First, tire ply is an ideal connecting structure for the non-pneumatic tire application because it is thin, and has a low bending stiffness with no resistance to compression or buckling. Tire ply has a high tensile stiffness and strength which is needed in the non-pneumatic tire application. Tire ply is also cheap, has a known durability, and is readily available.

As shown in FIG. **4**, the reinforcement layer is preferably oriented so that it makes an angle alpha with respect to the radial direction. The angle alpha can help pretension the reinforcement **400** and also increase and tune the lateral stiffness of the tire. This results in a non-pneumatic tire having angled sidewalls. The angle alpha is measured with respect to the radial direction, and may be +/−40 degrees, and more preferably, +/−20 degrees. The angle alpha can be tuned as desired using an axial adjustment feature of the rim **502**. The rim **502** may be axially adjusted to narrow or expand the axial rim width. This axial adjustment controls the ply tension, allowing the tire lateral stiffness to be adjusted independent of the radial stiffness. The rim may be adjusted by a tensioning member or bolt **504** that is mounted in the opposed rim parallel walls **506**,**508**.

It is advantageous to locate the reinforcement layer radially outward of the shear band because it eliminates the tensile stress on the bond between the shear band and load carrying member or connecting structure. This advantage is especially important when the shear band and the play are dissimilar materials. The interface of the shear band and the connecting web is typically a point of failure due to the interface of dissimilar materials.

FIG. **5** illustrates an alternate embodiment of the ply spokes. The reinforcement layer is formed by looping **615** a plurality of strips about a respective bead **430**, so that the first end **600** and the second end **610** are located adjacent each other. The first and second ends **600**,**610** are preferably located radially outward of the shear band or formed in the shear band. The strips are thus looped about the bead, forming a first sidewall. A plurality of strips are looped about a bead **430** on the other side of the tire to form a second sidewall. A first end **700** of a reinforced strip is looped around a bead **430** and then extended radially outward so that the second end **710** is mounted over the shear band and adjacent the first end **700**. The first and second ends **600**,**610** of the first strip mounted on the right side of the tire may extend axially across the shear band to the left side **302** of the shear band. The first and second ends **700**,**710** mounted on the left side of the tire may also likewise extend axially across the shear band to the right side **304** of the shear band. The ends **700** may overlap with the strip ends **600**. The ends **700** may overlap with the strip ends **600** in an alternating fashion.

Alternatively, the reinforced ply strip may be continuously wound from one side of the tire to the other, forming a plurality of radial ply spokes as shown in FIG. **6**. The reinforced strips are located radially outward of the shear band **300**. The reinforced strip is wound about a first bead, in a continuous manner to the other bead and so forth, forming an endless ply. The ply spokes or strip are preloaded in tension.

The reinforcement structure **400** need not be positioned radially outward of the shear band. The reinforcement structure may be positioned radially inward and underneath the shear band (not shown).

Alternatively, the first ends **402***a,b* of the reinforced strips **400** may be positioned between the reinforcement layers of the shear band, as shown in FIG. **7**. The reinforced strips **400** may extend completely across the shear band in the axial direction as shown in FIG. **8**. Furthermore, although the invention has been described as ply strips oriented to form spokes that extend in the radial direction, a layer of ply **800** as shown in FIG. **9** may be used to form any of the constructions described herein. Although the invention may be utilized with a conventional tire rim, the invention may also be used with a conventional tire rim split in half as shown in FIG. **10**, which may provide for axial adjustment between the rims. Applicants understand that many other variations are apparent to one of ordinary skill in the art from a reading of the above specification. These variations and other variations are within the spirit and scope of the present invention as defined by the following appended claims.

What is claimed:

1. A non-pneumatic tire comprising

a ground contacting annular tread portion;

a shear band; and

a reinforcement structure positioned radially inward of the tread, said reinforcement structure being formed from a plurality of strips, wherein each strip has a first end located radially outward of the shear band and a second end secured to a bead, wherein the plurality of strips do not extend completely across the annular tread portion.

2. The non-pneumatic tire of claim **1** wherein the reinforcement structure is a layer of ply.

3. The non-pneumatic tire of claim **1** wherein the reinforcement structure is a plurality of strips of material.

4. The non-pneumatic tire of claim **3** wherein the strips are reinforced with one or more parallel reinforcements.

5. The non-pneumatic tire of claim **1** wherein the reinforcement structure is angled inwardly.

6. The non-pneumatic tire of claim **1** wherein the strips are oriented in the radial direction forming ply spokes.

7. The non-pneumatic tire of claim **1** wherein the non-pneumatic tire is mounted on a standard rim.

8. The non-pneumatic tire of claim **1** wherein the non-pneumatic tire is mounted on a rim, wherein the rim is axially adjustable.

9. The structurally supported non-pneumatic tire of claim **4** wherein the angle alpha is in the range of −20 to +20 degrees.

10. A non-pneumatic tire comprising

a ground contacting annular tread portion;

a shear band; and

a reinforcement structure positioned radially inward of the tread, said reinforcement structure being formed from a plurality of strips, wherein each strip has a first end located between the shear band and a second end secured to a bead, wherein the plurality of strips do not extend completely across the annular tread portion.

* * * * *